Methodology for Flow and Salinity Estimates in the Sacramento-San Joaquin Delta and Suisun Marsh

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Chapter 8: CALSIM Water Quality Operating Rules to Meet Delta Wetlands Water Quality Management Plan

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8 CALSIM Water Quality Operating Rules to Meet Delta Wetlands Water Quality Management Plan

8.1 Introduction

CALSIM II requires operating rules to release flows to meet water demands and water quality standards. For the Delta water quality standards, CALSIM II uses an Artificial Neural Network (ANN) to determine if salinity standards are being met and adjusts the water supply in the Delta to meet those standards.

The operation of the proposed In-Delta Storage Project would affect water quality in a way that cannot currently be addressed by the ANN. ANN is trained using rimflows, exports, and Delta Cross Channel gate operations and provides salinity water quality results at select locations. The ANN has not been trained to provide salinity water quality results using a Delta hydrology that includes flows being taken and released from In-Delta Storage islands.

Additionally, there are other water quality criteria that have been listed in the Water Quality Management Plan (2000) for the In-Delta Storage project that are not addressed in CALSIM II. These also include criteria for total organic carbon (TOC), total trihalomethanes (TTHM), bromate (BRM), disolved oxygen (DO), and temperature. Figure 8.1 shows a summary of the criteria. All of the water quality constraints are described in greater detail in Hutton (2001).

The water quality criteria for the In-Delta Storage project requires that the water releases from the project islands do not adversely impact the ecosystem (temperature and DO) and do not degrade drinking water quality (TOC, Cl, TTHM, and BRM). This paper will address the preliminary work done in determining operating rules for CALSIM II that will address the In-Delta Storage Water Quality criteria. Developing these water quality rules will be an iterative process.

CRITERIA	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
WATER QUALITY CRITERIA, IN-DELTA STORAGE PROGRAM												
TOTAL ORGANIC CARBON (TOC)												
All export Locations (14-day average) (1)						<4.0 mg/L limit						
All export locations and Water TP intakes (14-day average) (2)					Incremental Increase <1.0 mg/L							
If TOC of stored water > TOC of channel water (3)		Discharge from Webb Tract or Bacon Island ranges from 40 cfs to 1,500 cfs depending on TOC										
CHLORIDE												
CCWD's intake and any urban water intake in the Delta (4)					< 10 mg/L Chloride							
Any urban intake in the Delta (5)					< 90% of salinity std.							
Limit discharge from Webb Tract and Bacon Island (6)			For chloride 0 - 250 mg/L, discharge 3,000 - 80 cfs									
DISINFECTION BYPRODUCTS (TTHM)												
Urban intake or treatment plant outlet (7)					< 64 µg/ L TTHM							
BROMATE												
Urban intake or treatment plant outlet (8)					< 8 µg/ L Bromate							
DISOLVED OXYGEN (DO)												
No discharge if DO in stored water is less than: (9)						< 6 mg/L						
No discharge if depressesDO of channel water to less: (10)						< 5.0 mg/L						
No discharge if DO in San Joaquin (Turner Cut to Stockton) (11)									< 6.0 mg/L			
TEMPERATURE												
No discharge if temperature differential (12)						>20° F						
For channel temp. 55° F to 66° F, limit increase to (13)						< 4° F						
For channel temp. 66° F to 77° F, limit increase to (14)						< 2° F						
For channel temp. > 77° F, limit increase to (15)						< 1° F						

FOOTNOTES

(1) Releases from storage reservoir ahould not cause the TOC concentration at any of the intakes of SWP, CVP, CCWD pumping plant, or urban water treatment plant (ALL INTAKES) to exceed 4.0 mg/L (14-day average).

(2) Incremental increase of TOC concentration at ALL INTAKES should not exceed 1.0 mg/L (14-day average).

(3) Discharge from Bacon Island and Webb Tract is limited to a declining scale if TOC concentration of stored water is higher than TOC of channel water

(4) Chloride concentrations at ALL INTAKES shall not ecxeed 10.0 mg/L.

(5) Operation of Delta Wetlands Project should not cause or contribute to salinity increase at ALL INTAKES if salinity at the intake is at 90% of an adopted standard.

(6) If chloride concentration of stored water is higher than of the channel water, the conbined discharge from storage islands will be limited depending on the incremental differencial.

(7) Modeled or predicted TTHM concentration at ALL INTAKES or the outlet of a water treatment plant should be caused by the Project to exceed 64 µg/ L.

(8) Modeled or predicted bromate concentration at ALL INTAKES or the outlet of a water treatment plant should be caused by the Project to exceed 8 µg/ L.

(9) Stored water will not be discharged if DO is less than 6 mg/L.

(10) Stored water will not be discharged if it would cause the DO of the mixture with channel water to drop less than 5.0 mg/L.

(11) Stored water will not be discharged if the operation would decrease the DO of San Joaquin River between Turner Cut and Stockton to less than 6.0 mg/L.

(12) Stored water will not be discharged in the channels if the temperature differential is more than 20° F .

(13) No discharge of stored water if it will increase the channel water temperature by more than 4° F when the channel water temperture is between 55° F and 66° F.

(14) No discharge of stored water if it will increase the channel water temperature by more than 2° F when the channel water temperture is between 66° F and 77° F.

(15) No discharge of stored water if it will increase the channel water temperature by more than 1° F when the channel water temperture is higher than 77° F.

Figure 8-1: Water Quality Criteria, In-Delta Storage Program (Bindra, 2001).

8.2 CALSIM II

Because CALSIM II is not designed for water quality modeling, determining if water quality standards are exceeded in the Delta is not an easy task. As previously discussed, CALSIM II uses an ANN to determine salinity at selected locations based on flows and Delta Cross Channel operation. Other water quality constraints would also require using information available from CALSIM II such as flows and would require implementing water quality modules within the code. In these situations, the processes affecting water quality would be simplified and would be a gross estimate of the effects of project operations.

There are several possible combinations of factors that can influence the operation of the projects. The various possible operations of the project to limit TOC at the urban intake locations are used to illustrate this point. To reduce the amount of TOC released from the islands the following operations could be considered:

- Water diverted onto the island could be constrained by the quality of intake water.
- The time the water is stored on the island, the temperature of the water and its depth will affect the quality of the water. The amount of release and when it is released could be based on these island storage factors.
- When the water is released from the project islands, it will have to meet water quality criteria at the urban intake locations. This meeting of the criteria could be addressed in the previous steps but could also be addressed by adjusting the amount of water that can be released.

Determining the operation that will optimize the quality and quantity of water released from the project islands will require iterations and analysis with DSM2. Discussed below are the various water quality criteria and factors that should be considered in determining operating rules.

8.3 Chloride

Diversions onto the project islands and releases from the islands will affect the hydrodynamics of the Delta system and could affect the transport of ocean salinity. This transport would affect the chloride levels. To address this issue, the ANN would be trained with project island releases and diversions.

The amount of flow diverted onto the reservoir islands in CALSIM II should be inversely proportional to the chloride levels at Old River at Rock Slough (the station closest to the project islands where that ANN determines quality). As the chloride levels increase, the amount of diversion decreases. This decrease in diversion is done to maintain low salinity levels within the reservoir. Because not all of the water may be diverted at one time, CALSIM II will need to calculate the changing concentration in the project reservoirs due to inflows and evaporation/precipitation.

The amount of water released will be determined by the effect that the release water has on quality. If the water has low levels of chloride, then the chloride quality will not be a controlling factor. If releasing the water results in a violation of the standard at Rock Slough, then the amount of water released will be less. A preliminary equation to prevent the standard from being violated was proposed by Wang (2001). The concept presented by Wang was further refined and modified by Easton (2002). The proposed operation is shown in Figure 8-2 and is described in the following paragraphs.

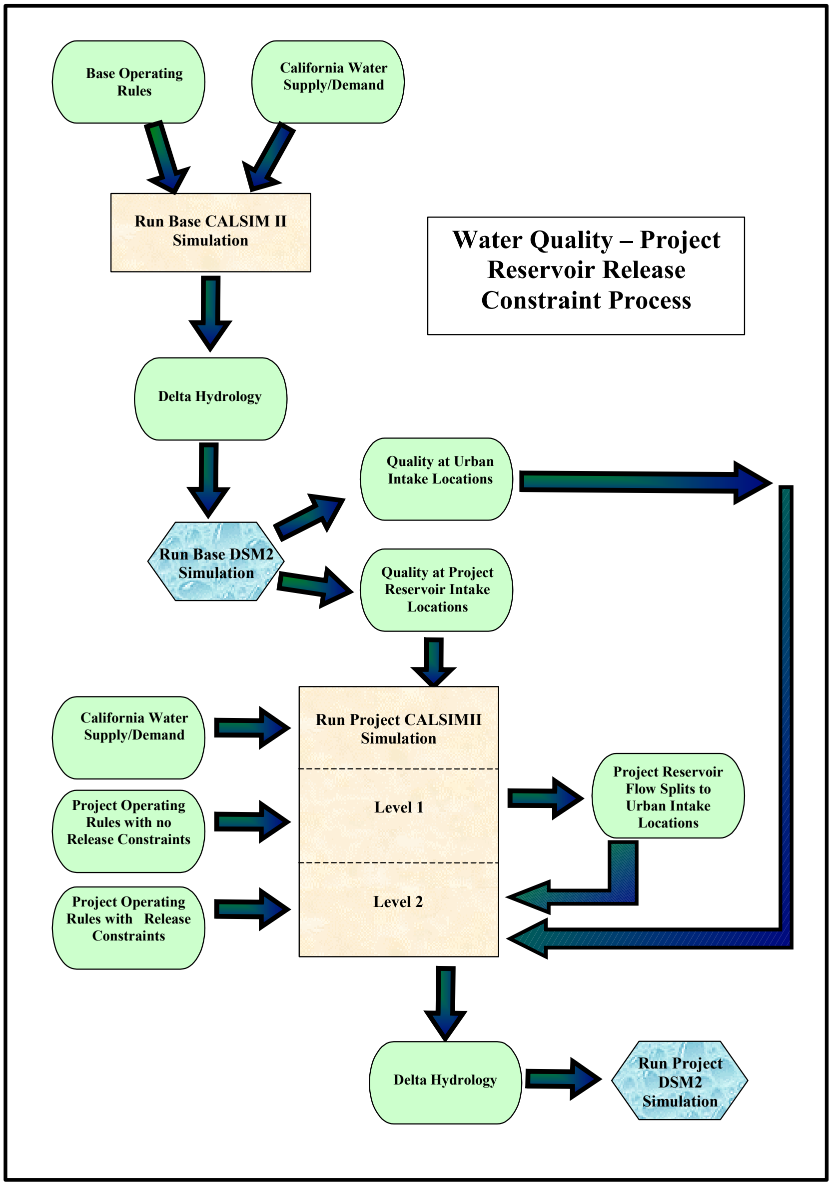

Figure 8-2: Water Quality – Project Reservoir Release Constraint Process.

8.3.1 Base Chloride Study

Begin the operation by running the CALSIM II base simulation. Using the Delta hydrology generated in that simulation, run a base DSM2 simulation. This simulation will generate a chloride concentration time series at various water quality locations in the Delta.

Use the base DSM2 chloride concentration time series generated at project intake locations as the island diversion concentrations in the CALSIM II project simulation. Also, use the base DSM2 chloride concentration time series generated at the Delta export locations as the chloride constraint basis of measure in the CALSIM II project simulation.

8.3.2 Project Study Using Chloride Constraints

Continue the operation by running the CALSIM II project simulation. This simulation is a multi-layered model that generates a dispersion mechanism in one layer for the application of the chloride constraints in another. Dispersion of chloride released from the islands is based on the split of exports without the chloride constraints.

For example, say Delta exports are pumped at the following rates without the chloride constraints: Tracy, 4,200 cfs; Banks, 5,600 cfs; and Contra Costa Water District (CCWD), 200 cfs. In the following model layer, island discharge and its associated chloride concentration would be fractionally dispersed to the three export locations as follows: Tracy 42%, Banks 56%, and CCWD 2%. Chloride constraints would be based on the resulting mixture of Delta water and island discharge at each export intake. It is assumed that all water coming off islands will go to one of the exports. This assumption is not necessarily true (especially for Webb Tract). Future modifications to the constraint equations could be made to account for water not being exported.

The constraint will limit the concentration of the project water at the urban intakes to be less then the base concentration plus 10 mg/L. Under the Water Quality Management Plan (WQMP), the project cannot exceed the base concentration by 10 mg/L.

Constraints for Tracy:

$$\frac{Q_1' C_1 + f_1 \left(Q_4 C_4 + Q_5 C_5 \right)}{Q_1} \leq C_1 + 10 \qquad \text{[Eqn. 8-1]}$$

$$Q_1' = Q_1 - f_1 \left(Q_4 + Q_5 \right) \qquad \text{[Eqn. 8-2]}$$

Constraints for Banks:

$$\frac{Q_2'C_2 + f_2\left(Q_4C_4 + Q_5C_5\right)}{Q_2} \le C_2 + 10 \qquad \text{[Eqn. 8-3]}$$

$$Q_2' = Q_2 - f_2\left(Q_4 + Q_5\right) \qquad \text{[Eqn. 8-4]}$$

Constraints for CCWD:

$$\frac{Q_3'C_3 + f_3\left(Q_4C_4 + Q_5C_5\right)}{Q_3} \le C_3 + 10 \qquad \text{[Eqn. 8-5]}$$

$$Q_3' = Q_3 - f_3\left(Q_4 + Q_5\right) \qquad \text{[Eqn. 8-6]}$$

where,

Q_1 = Tracy export rate (cfs),
Q_2 = Banks export rate (cfs),
Q_3 = Contra Costa export rate (cfs),
Q_4 = Bacon Island Release Rate (cfs),
Q_5 = Webb Tract Release Rate (cfs),
Q_1' = Export of water not released from IDS islands at Tracy (cfs),
Q_2' = Export of water not released from IDS islands at Banks (cfs),
Q_3' = Diversion of water not released from IDS islands at CCWD (cfs),
C_1 = Chloride Concentration at Tracy (mg/L) from base DSM2 simulation,
C_2 = Chloride Concentration at Banks (mg/L) from base DSM2 simulation,
C_3 = Chloride Concentration at CCWD (mg/L) from base DSM2 simulation,
C_4 = Concentration of Bacon Island Water (mg/L),
C_5 = Concentration of Webb Tract Water (mg/L),
f_1 = Dispersion fraction at Tracy,
f_2 = Dispersion fraction at Banks, and
f_3 = Dispersion fraction at CCWD.

From preliminary DSM2 simulations that were made previously to evaluate the In-Delta Storage project, the 10 mg/L change in the chloride constraint was violated during time periods that did not have significant project reservoir diversions or releases. The violation occurred because of a general reoperation of the system. To address this, additional operational rules were implemented. In these rules, chloride quality in the project simulation could not exceed the CALSIM II base case quality by 10 mg/L or more. Due to differences in how DSM2 and ANN calculate quality, the 10 mg/L chloride constraint was still occasionally exceeded in the DSM2 simulation. Future work may tighten the rules in CALSIM II so that no degradation of water quality in the project simulation occurs.

8.4 Total Organic Carbon

There are three areas that have to be considered when looking at TOC quality and its effects on drinking water quality. The first is the quality of the water diverted onto the project islands, the second is the increase in TOC in the project reservoirs due to the interaction with the peat soil and bioproductivity, and the third area is the release quality and quantity from the project islands.

Diversion of water onto the reservoir islands takes place in excess flow conditions. TOC levels tend to be high during the first major precipitation event. Water diverted to the reservoir island during this time will have higher TOC than the water in the channels during times of reservoir island release. Operating rules may need to consider limiting the amount of water diverted during these events.

While the water stays in the project island reservoir, it interacts with the peat soil and the TOC levels increase (Jung, 2001). Additionally, TOC increases due to bioproductivity (Duvall, 2001). This increase depends on the length of time the water is stored, the depth of the water, and the temperature of the water, among other factors. Operating rules may need to consider these factors in determining when and how much water can be released. A possible operating rule to limit the increase of TOC would be to release the project island water first to meet south of Delta demands instead of releasing from upstream reservoirs (which would decrease the retention time on the island reservoirs). Furthermore, a rule to retain a small amount of water in the project island may be made to limit bioproductivity.

Since CALSIM II does not model the changing TOC or dissolved organic carbon (DOC) levels in the Delta channels, an attempt was made to correlate DOC[1] with Delta island consumptive use (DICU) with the intention of using the relationship to develop project island diversion rules. No strong correlation was found (Anderson, 2001).

Using a relationship developed by Jung (2001), the interaction between the peat soil and the water can be modeled in CALSIM II (Pandey, 2001). Jung's relationship is already incorporated into DSM2, as described in Chapter 9.

Similar to the rules for chloride, the amount of water released will be determined by the release water's effect on TOC. If the release has lower levels of TOC, then the TOC quality will not be a controlling factor. If releasing the water results in a violation of the WQMP change in TOC 1 mg/L criteria, then the amount of water released will be reduced. As a preliminary estimate of release flows that will not violate the TOC criteria, Equations 8-7 through 8-9 could be used.

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[1] DOC is used as a surrogate for TOC in the simulations.

8.4.1 Base DOC Study

Begin the operation by running the CALSIM II base simulation. Using the Delta hydrology generated in that simulation, run a base DSM2 simulation. This simulation will generate concentration time series at the project reservoir intake locations and at the urban intake locations.

Use the base study DOC concentration time series generated at project intake locations as reservoir island diversion concentrations in the CALSIM II project simulation. Also, use base study DOC concentration time series generated at Delta export locations as the DOC constraint basis of measure in the CALSIM II project simulation.

8.4.2 Project Study Using DOC Constraints

Continue the operation by running the CALSIM II project simulation. This simulation is a multi-layered model that generates a dispersion mechanism in one layer for the application of the DOC constraints in another. Dispersion of DOC released from the islands is based on the split of exports without the DOC constraints.

For example, say Delta exports are pumped at the following rates without the DOC constraints: Tracy, 4,200 cfs; Banks, 5,600 cfs; and CCWD, 200 cfs. In the following model layer, island discharge and its associated DOC concentration would be fractionally dispersed to the three export locations as follows: Tracy 42%, Banks 56%, and CCWD 2%. DOC constraints would be based on the resulting mixture of Delta water and island discharge at each export intake. It is assumed that all water coming off islands will go to one of the exports. This assumption is not necessarily true (especially for Webb Tract). Future modifications to the DOC constraint equations will be made to account for water not being exported.

Calculate the constraint for each location. The constraint will limit the concentration of the project water at the urban intakes to less than the base concentration plus 1 mg/L. Under the WQMP, the project cannot exceed the base concentration by 1 mg/L.[2]

Constraint for Tracy:

$$\frac{Q_1' C_1 + f_1\left(Q_4 C_4 + Q_5 C_5\right)}{Q_1} \le C_1 + 1 \qquad \text{[Eqn. 8-7]}$$

[2] The 1 mg/L constraint applies except when the base case concentrations are between 3-4 mg/L. When the concentrations are between 3-4 mg/L, the constraint limits the increase in TOC such that it does not exceed 4 mg/L.

Constraint for Banks:

$$\frac{Q_2'C_2 + f_2\left(Q_4C_4 + Q_5C_5\right)}{Q_2} \leq C_2 + 1 \qquad \text{[Eqn. 8-8]}$$

Constraint for CCWD:

$$\frac{Q_3'C_3 + f_3\left(Q_4C_4 + Q_5C_5\right)}{Q_3} \leq C_3 + 1 \qquad \text{[Eqn. 8-9]}$$

where,

C_1 = DOC Concentration at Tracy (mg/L) from base DSM2 simulation,

C_2 = DOC Concentration at Banks (mg/L) from base DSM2 simulation,

C_3 = DOC Concentration at CCWD (mg/L) from base DSM2 simulation,

C_4 = Concentration of Bacon Island Water (mg/L), and

C_5 = Concentration of Webb Tract Water (mg/L).

8.5 Bromate

Using the Ozekin equation in attachment 3 of the Water Quality Management Plan (2000), which was further derived and simplified in Hutton (2001), bromate can be described as a function of DOC and bromide.

$$Bromate = C_2 \times DOC^{0.31} \times Br^{0.73} \qquad \text{[Eqn. 8-10]}$$

Both DOC and bromide can be determined using relationships between TOC (Hutton, 2001) and electrical conductivity and chloride (Suits, 2001). When water is diverted, stored, and released, bromate will also have to be incorporated into the CALSIM II operating constraints if after preliminary simulations, it is discovered that bromate is a controlling constituent.

8.6 Total Trihalomethanes (TTHM)

Using the Malcolm Pirnie equation in attachment 3 of the WQMP, which was further derived and simplified in Hutton (2001), TTHM can be described as a function of DOC, and bromide, ultraviolet light absorbance (UVA), and temperature (T).

$$TTHM = C_1 \times DOC^{0.228} \times UVA^{0.534} \times \left(Br + 1\right)^{2.01} \times T^{0.48} \qquad \text{[Eqn. 8-11]}$$

When water is diverted, stored, and released, TTHM will also have to be incorporated into the CALSIM II operating constraints if, after preliminary simulations, it is discovered that TTHM is a controlling constituent.

8.7 Temperature and DO

Adequate temperature and DO rules in CALSIM II will be difficult to implement due to some precise release rules criteria. Accurately modeling temperature and DO changes due to diversions and releases in DSM2 will be difficult due to inadequate amounts of observed data to calibrate DSM2.

Analysis of the effects of releases on temperature and DO levels is currently being accomplished by using a spreadsheet model to evaluate the local effects (Yokoyama, 2001).

8.8 References

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